Baryon “stopping” at high energy and entropy production constraints from the initial state

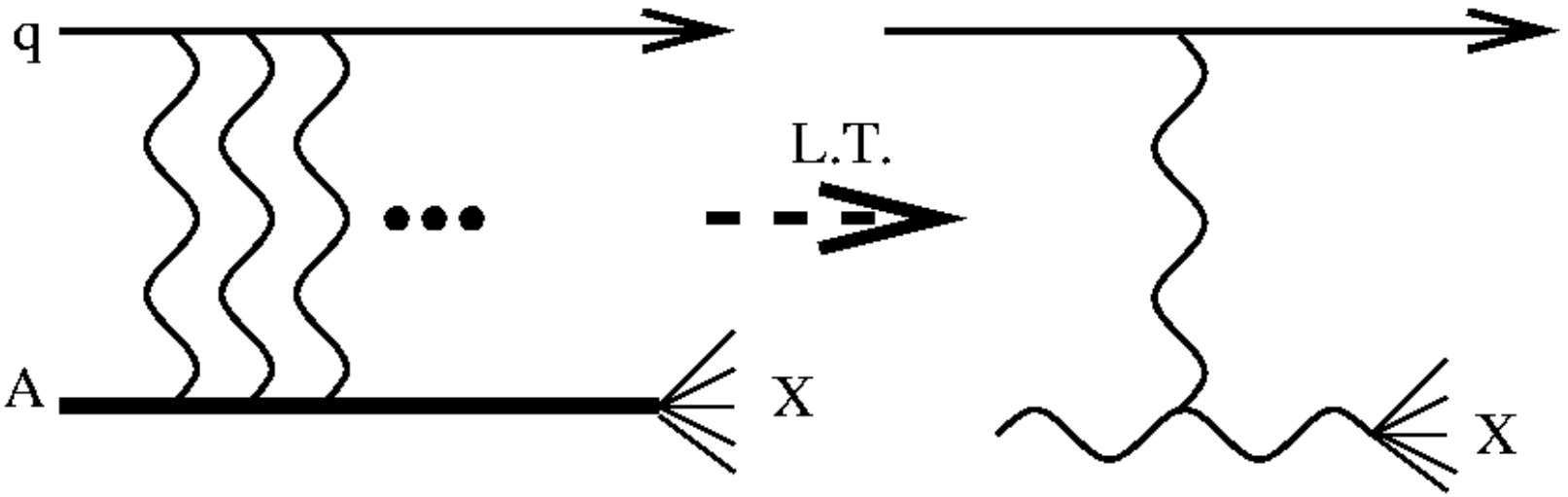
- Baryon “stopping” / shattering in high-energy pA

  L. Gerland, A.D., M. Strikman, PRL 90 (2003)
  J. Albacete, Yu. Kovchegov, NPA 781 (2007)
  Y. Mehtar-Tani, G. Wolschin, arXiv:0811.1721

- Constraints on entropy production in hydro stage (due to shear viscosity)

  Lublinksy and Shuryak, PRC (2007)
  A.D., Y. Nara, E. Molnar, PRC (2007)

Quark-Nucleus Scattering in Eikonal limit



Quark Scattering Amplitude :

$$\langle q\ out \mid p\ in \rangle = \bar{u}(q)\ \tau(q,p)\ u(p)$$

with

$$\tau(q,p) = 2\pi\,\delta(p^- - q^-)\,\gamma^- \int \mathrm{d}^2x_t\,[V(x_t)-1]\ e^{ix_t(q_t-p_t)}$$

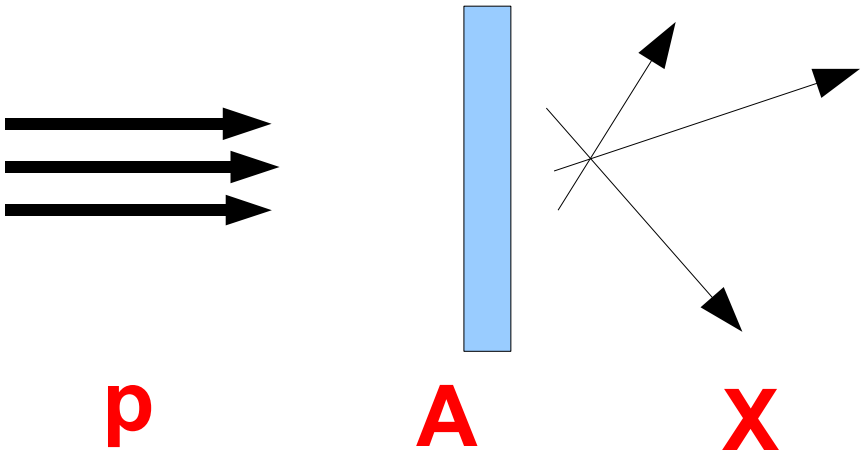
$$V(x_t) = \mathcal{P}\exp\left(-ig^2 \int_{-\infty}^{\infty} \mathrm{d}x^- \frac{1}{\partial_t^2}\,\rho^a(x^-,x_t)\,t^a\right)$$

Baryon "stopping" at high energy: shattering the proton

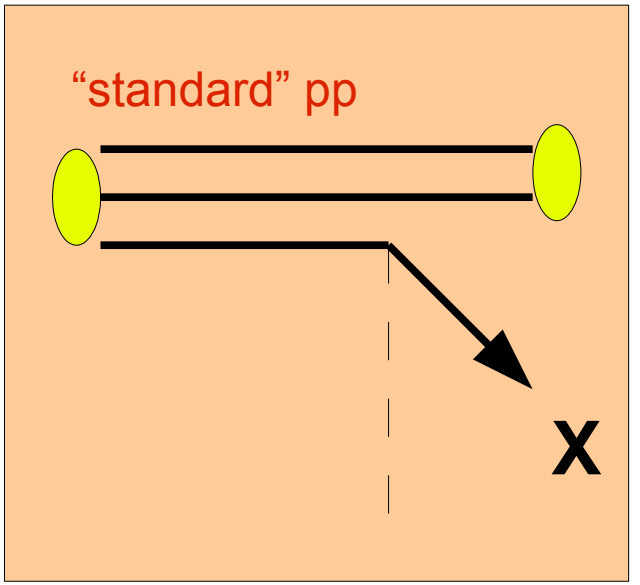
Probability for quark to be scattered to q_t~0 (<u>with</u> color exchange !) :

$$\int_0^{\Lambda} \mathrm{d}^2 q_t \frac{\mathrm{d}\sigma^{\mathrm{in}}}{\mathrm{d}^2 b \mathrm{d}^2 q_t} \simeq 1 - \exp\left(-\frac{\pi\Lambda^2}{Q_s^2 \log Q_s/\Lambda}\right) \simeq \frac{\pi\Lambda^2}{Q_s^2 \log Q_s/\Lambda}$$

→ **suppression of "beam-jet remnants" (soft physics) on dense target**



$$\langle q_t \rangle \sim Q_s$$



<u>All partons resolved at scale Qs, coherence of proton destroyed completely.</u>

Assuming independent fragmentation of scattered partons:

$$x_F \frac{d\sigma^{pA\to h}}{dx_F\, d^2k_t\, d^2b} = \frac{1}{(2\pi)^2} \int_{x_F}^{1} dx\, \frac{x}{x_F} f_{q/p}(x, Q_s^2)\, N_F\left(\frac{x}{x_F} k_t, b\right) D_{h/q}\left(\frac{x_F}{x}, Q_s^2\right)$$

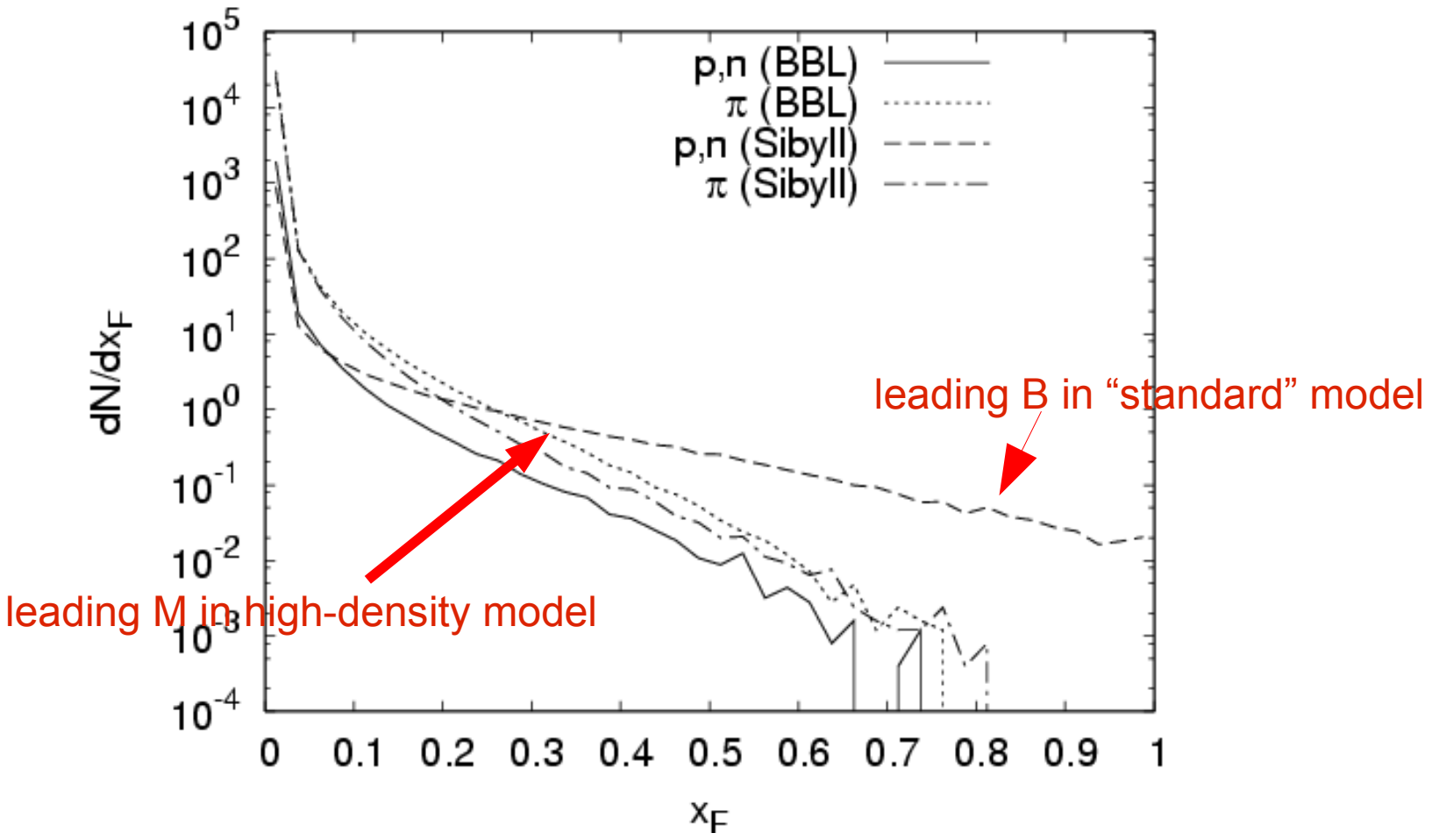
$$x_F \frac{d\sigma^{pA\to B-\overline{B}}}{dx_F\, d^2b} = \int_{x_F}^{1} dx\, \frac{x_F}{x} \left[f_{q/p}(x, Q_s^2) - f_{\bar{q}/p}(x, Q_s^2)\right] \left[D_{B/q}\left(\frac{x_F}{x}, Q_s^2\right) - D_{\overline{B}/q}\left(\frac{x_F}{x}, Q_s^2\right)\right] \frac{d\sigma^{qA}}{d^2b}$$

$$\frac{d}{d\log Q_s^2} \langle z^n \rangle_{B-\overline{B}} = \frac{\alpha_s(Q_s)}{\pi} \gamma_{qq}^{(0)}(n+1) \langle z^n \rangle_{B-\overline{B}}$$

However, recombination of leading quarks may still play a role at RHIC energies (especially for min bias pA)

Even stronger "stopping" may indicate need for longitudinal momentum transfer / going beyond eikonal approx !

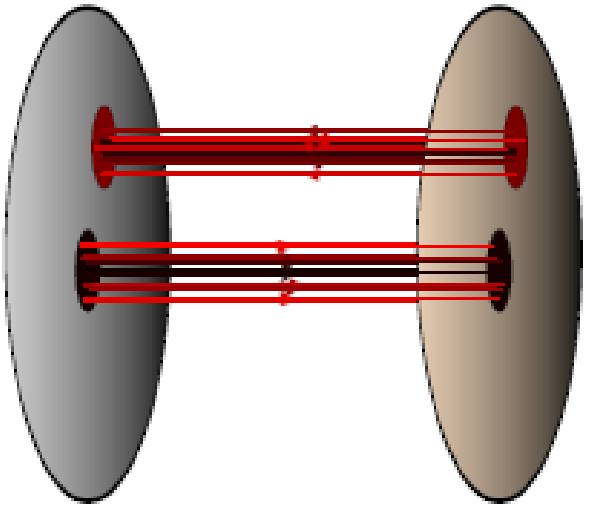
p+^{14}N, E=10^9 GeV



High-density target shifts baryon charge
(due to loss of coherence / fragmentation of projectile)

Testing decoherence of projectile + Eikonal limit in:

- does M/B ratio in forward region increase with centrality / energy in pA/dA ?
- test rapidity correlations from flux tubes:



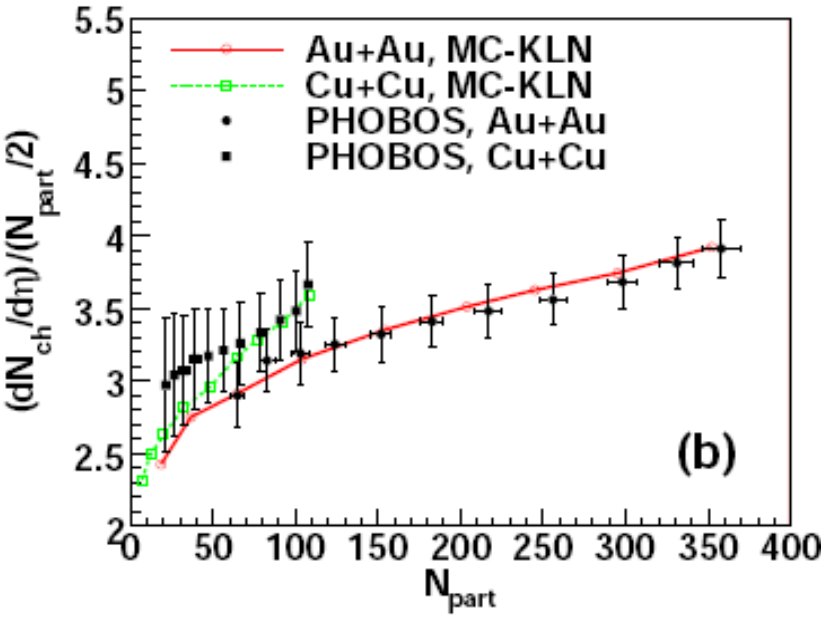
Entropy production / thermalization time constraints from initial CGC multiplicity

very good "fit" of centrality dependence of dN/dy from kt-factorization approach with saturating uGD:

$$\frac{dN}{dy} \sim \int d^2x_t \int \frac{d^2p_t}{p_t^2} \int d^2k_t\, \alpha_s\, \Phi_A(x_1, (p_t+k_t)^2/4, x_t)\, \Phi_B(x_2, (p_t-k_t)^2/4, x_t)$$

actually, reasonably good fit even with soft+hard models w/o "final state" rescattering such as HIJING event generator

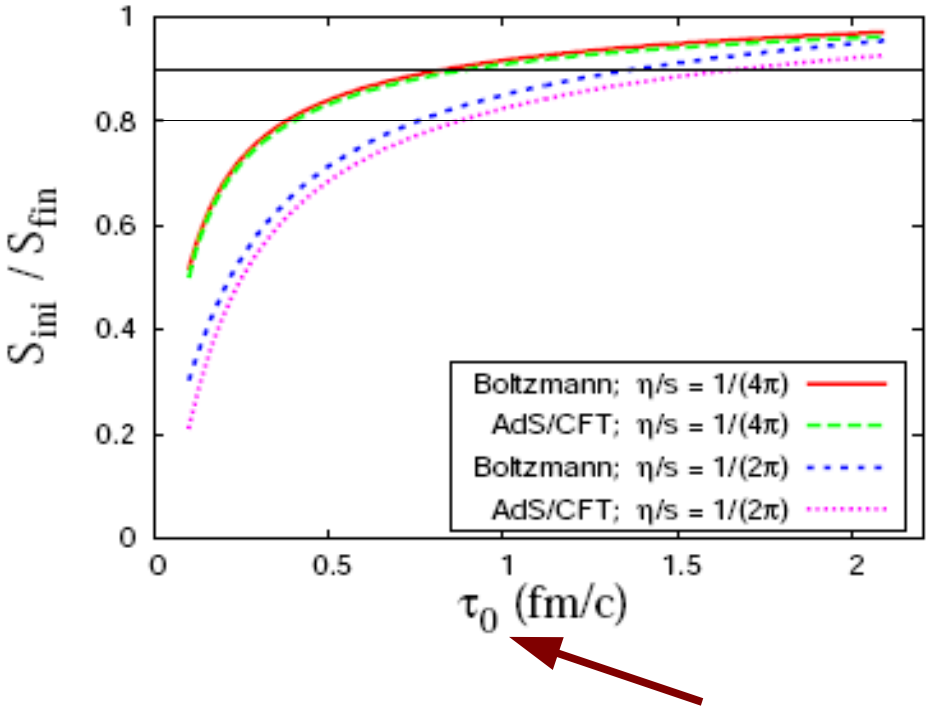
Hirano, Nara, arXiv:0904.4080



room for centrality dependent entropy production from viscous hydro evolution ?

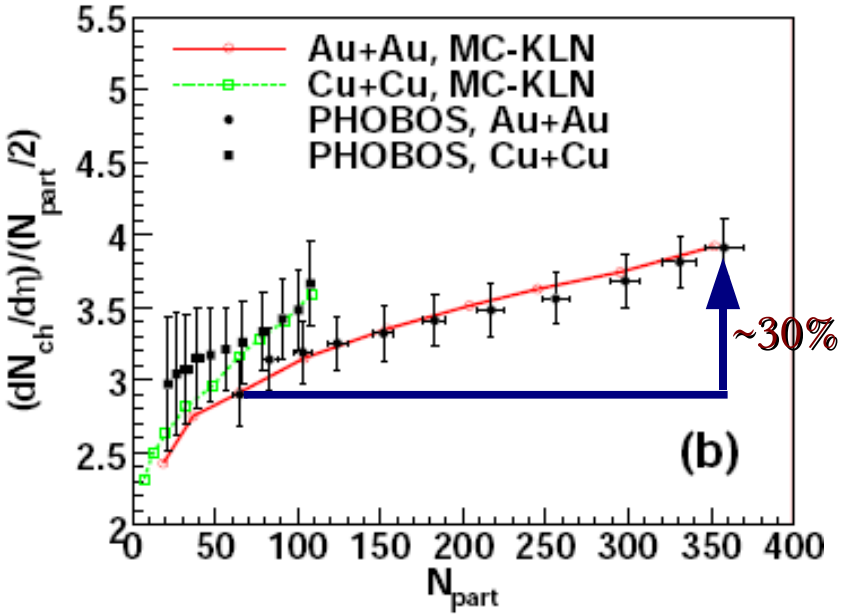
entropy production from viscous (IS) hydro:

A.D., Nara, Molnar, arXiv:0706.2203



initial time for hydro

★ initial-state models constrain η/s and τ_0



★ η/s=1/2π and τ_0=0.6 fm would account for the entire ~30% from N_{part} = 60 ⟶ 360, requires flat initial dN/dy / N_{part} !

★ note also that hard production increases by factor of $(360/60)^{1/3}$ = 1.8 !

Summary / Outlook

- Baryon "stopping" at high energies is not well understood;
  "pA" data (forward region) could help!

- at high E:
  - leading partons don't "loose energy"
  - energy of midrapidity particles small

$$\int_0^{\langle p_t \rangle / \sqrt{s}} \frac{dx}{x} x \sim \frac{\langle p_t \rangle}{\sqrt{s}}$$

- does M/B ratio in forward region increase with centrality / energy in pA/dA ?

- rapidity correlations from flux tubes ?

- centrality dependence of initial particle production constrains thermalization time / (shear) viscosity of fluid